3.2.9. PYRGEOMETER COMPARISON

Introduction

The broadband hemispheric downwelling longwave irradiance at the earth's surface ($F_{IR}\downarrow$) is a significant component of the surface energy budget. It is a function of both the thermal structure and the optical structure of the atmosphere and, therefore, includes radiation because of the greenhouse properties of atmospheric constituents. Measurements of $F_{IR}\downarrow$ typically made by pyrgeometers, have uncertainties thought to be of the same magnitude or larger than the potential change in $F_{IR}\downarrow$ because of anthropogenic greenhouse forcing. Several factors contribute to the uncertainties in these measurements: lack of an adequate traceable, absolute calibration standard; variations in calibration techniques; and uncertainties in the thermal balance within the instruments.

A recent intercomparison conducted with a suite of pyrgeometers, a new scanning absolute IR radiometer (sky-scanner) (R. Philipona, personal communication, 1999), and radiative transfer model calculations suggests that significant reductions in the uncertainty of pyrgeometer measurements may be achieved. A comparison of averaged nighttime measurements shows excellent agreement between pyrgeometer and sky-scanner measurements (within -0.1 ± 0.2 W m^{-2} out of 280 W m^{-2}) (R. Philipona, personal communication, 1999) when all pyrgeometers are calibrated using a common technique. The development of the sky-scanner, which utilizes a cavity detector referenced in near-real time to a blackbody calibration target, suggests that a stable reference standard radiometric scale for IR (similar to the World Radiometric Reference scale for shortwave) is achievable and transferable to pyrgeometers for field use. The modeled irradiances (calculated using MODTRAN4 [*Anderson et al.,* 1999] with radiosonde data as input) exhibit a positive mean bias of 1.0 W m^{-2} versus the measurements. The radiative impacts of other model components unspecified by the sonde data (CFCs and aerosols, for example) are being evaluated.

Instrumentation and Models

The first International Pyrgeometer and Absolute Scanning Radiometer Comparison (IPASRC-I) was held at the Department of Energy Atmospheric Radiation Measurement (ARM) program's Southern Great Plains Cloud and Radiation Testbed (CART) site at Lamont, Oklahoma, during September 20-October 1, 1999. A suite of 15 pyrgeometers and the sky-scanner were deployed at the site's Radiometer Calibration Facility (RCF). The pyrgeometers measure the spectrally integrated (e.g., approximately 3.5-50 μm for Eppley model PIR pyrgeometers), horizontally incident longwave irradiance. All pyrgeometers had user-supplied calibrations. In addition, all pyrgeometers were calibrated by CMDL and seven pyrgeometers were calibrated by Physikalish-Meteorologisches Observatorium Davos (PMOD) prior to the field experiment. The CMDL calibrations were performed using a method similar to that described by *Albrecht and Cox* [1977]. The PMOD calibration technique is described by *Philipona et al.* [1995].

The sky-scanner is a directional instrument that measures the normal, unfiltered, spectrally integrated atmospheric longwave irradiance. This irradiance is measured at multiple directions, and then the measurements are cosine-weighted and integrated over the solid angle to produce the horizontally incident irradiance. The sky-scanner periodically measures a temperature-controlled blackbody target, which allows for absolute calibration. ARM performs periodic radiosonde launches from a site located near the RCF. These nearly co-located sonde data can be applied in radiative transfer models to simulate the downwelling irradiances observed by the instruments and help account for instrumental differences in spectral range and implementation. MODTRAN4, an Air Force radiative transfer algorithm with flexible simulation capabilities, was chosen for this use.

Data Analysis

Measurements were taken at 1-s intervals for half-hour periods during the day and night over the course of 5 clear days. Pyrgeometer measurements were converted to irradiance using first the user-supplied calibrations, then the CMDL calibrations, and finally (for seven of the pyrgeometers) the PMOD calibrations. The measurements were averaged over each half hour for each instrument, and then the pyrgeometers were further averaged by calibration grouping. Sonde data (temperature, pressure, relative humidity) were obtained for the launch nearest in time to the observations. The vertical resolution of the sonde data was reduced to levels appropriate to MODTRAN4; these reduced-resolution data were validated by running several test cases with a version of MODTRAN4 specially modified at CMDL to accept the full 2000+ layers of sonde data. Model calculations were performed to match the spectral range of the sky-scanner. Because the calculations were not completely defined by the sonde data, other input parameters (specifically CFCs and aerosols) were set at realistic default values.

Under the four nighttime comparisons, the agreement between the averaged user-calibrated pyrgeometers and the sky-scanner is within 1.6 ± 0.4 W m^{-2} out of 280 W m^{-2}, while for PMOD-calibrated pyrgeometers the agreement is within -0.7 ± 0.4 W m^{-2} (Figure 3.27). If the CMDL calibrations are employed, the agreement is exceptional, within -0.1 ± 0.2 W m^{-2}. However, significant differences exist among the 15 pyrgeometers. The spread, averaged over all nighttime measurements, is 8.4 W m^{-2} with CMDL calibrations, 3.4 W m^{-2} with PMOD calibrations, and 11.9 W m^{-2} with user calibrations. These results are

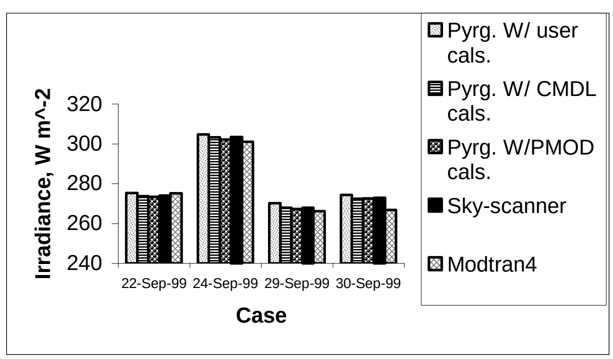

Fig. 3.27. IR irradiances from user-calibrated pyrgeometers, CMDL-calibrated pyrgeometers, PMOD-calibrated pyrgeometers, the sky-scanner instrument and MODTRAN4 model results for four nighttime comparisons.

consistent with prior estimates of the uncertainty associated with single measurements (±10 W m^{-2} [*Philipona et al.,* 1995] or about ±5% [*Dutton*, 1993]). Future intercomparisons are being planned that will incorporate other absolute scanning radiometer instruments, as available, and additional sites.

The MODTRAN4-modeled irradiances exhibit a somewhat consistent positive mean bias of 1.0 W m^{-2} relative to the sky-scanner measurements. Potential sources of the bias include the use of default values for CFCs and aerosols, as mentioned previously, and the treatment of the water vapor continuum within the model. An investigation into the magnitude of the influence of CFCs and aerosols on $F_{IR}\downarrow$ suggests that the effect of aerosols is significant compared to the size of the bias (Figure 3.28), while that of CFCs is not. Further work is being done to evaluate the influence of the water vapor continuum treatment.

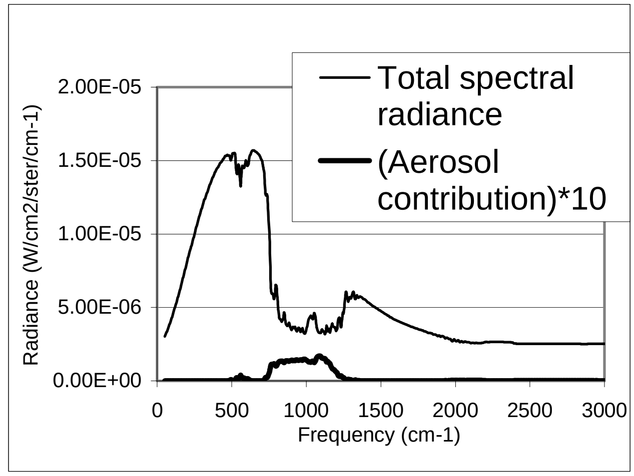

Fig. 3.28. Downwelling spectral irradiance (offset by +2.5 × 10^{-6}) and the contribution by aerosols (scaled up by a factor of 10). The aerosol spectrum accounts for 2 W m^{-2}.